# INSTRUCTION MANUAL

B+K PRECISION 830

## Autoranging CAPACITANCE METER

B+K PRECISION DYNASCAN CORPORATION

# WARRANTY SERVICE INSTRUCTIONS

1. Refer to the MAINTENANCE section of your B & K-Precision instruction manual for adjustments that may be applicable.

2 If the above-mentioned procedures do not correct the problem you are experiencing with your unit, pack it securely (preferably in the original carton or double-packed). Enclose a letter describing the problem and include your name and address. Deliver to, or ship PREPAID (UPS preferred) to the nearest B & K-Precision authorized service agency (see list enclosed with unit).

If your list of authorized B & K-Precision service agencies has been misplaced, contact your local distributor for the name of your nearest service agency, or write to:

**Service Department**

B & K-Precision Product Group
DYNASCAN CORPORATION
2815 W. Irving Park Rd.
Chicago, Illinois 60618

## USEFUL CONVERSIONS

| pF | nF | $\mu$F | mF | FARAD |
|---|---|---|---|---|
| 1,000 | 1.0 | 0.001 | | |
| 10,000 | 10.0 | 0.01 | | |
| 100,000 | 100.0 | 0.1 | | |
| 1,000,000 | 1000.0 | 1.0 | 0.001 | |
| | 10,000 | 10. | 0.01 | |
| | 100,000 | 100.0 | 0.1 | |
| | 1,000,000 | 1000.0 | 1.0 | 0.001 |
| | | 10,000 | 10.0 | 0.01 |
| | | 100,000 | 100.0 | 0.1 |
| | | 1,000,000 | 1000.0 | 1.0 |

pF = picofarads ($10^{-12}$)
nF = nanofarads ($10^{-9}$)
$\mu$F = microfarads ($10^{-6}$)
mF = millifarads ($10^{-3}$)

# INTRODUCTION

The B & K-Precision Model 830 Autoranging Capacitance Meter gives a direct reading of capacitance on a 3-½ digit liquid crystal display. The autoranging feature automatically selects the range with the highest resolution. Ten full scale ranges of 199.9 picofarads to 199.9 millifarads include virtually all capacitors used in electronics equipment. A selectable range hold feature prevents the range from resetting when a capacitor is removed, for faster batch testing of large value capacitors. The instrument has application in electronic engineering labs, production, service shops, and schools. It can be used to check tolerance, sort values, select precision values, measure unmarked capacitors, select matched sets, and measure cable or switch capacitance. Its battery operation, light weight, and small size make it a truly portable instrument.

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# OPTIONAL ACCESSORIES

### BC-28 ADAPTER/CHARGER

Permits use of rechargeable batteries (BP-28 Battery Pack only — not for use with alkaline or zinc-carbon batteries) and recharges batteries from 105-130 VAC, 60 Hz AC power. Completely recharges batteries overnight (16 hours). Meter can be operated while batteries are recharging.

### BP-28 BATTERY PACK

Includes four Nicad rechargeable batteries. Gives at least 12 hours continuous operation or 4 weeks of typical intermittent use on each charge. Recharges in 16 hours.

### LC-28 CARRYING CASE

Offers convenience and protection while transporting the instrument. Sturdy grained leatherette construction, rugged snap fasteners, handle. Cover swings away to permit use of meter while in carrying case. Stowage for test leads and manual.

### CF-10 COMPONENT FIXTURE

Component holding fixture with quick insert and release clips permits fast batch testing of axial lead capacitors. Adjustable to accomodate most physical sizes.

# SPECIFICATIONS

### CAPACITANCE

| | |
|---|---|
| **Range** | 10 ranges, fully automatic with range hold. Full scale value from 199.9 pF to 199.9 mF.<br>AUTO: between 180 and 1999 counts.<br>HOLD: between 0 and 1999 counts. |
| **Resolution** | 0.1 pF on lowest range and 0.05% of full scale on all ranges. |
| **Accuracy** | AUTO: 0.2% of reading, ±0.5 pF, ±1 digit to 19.99 μF. 1.0% of reading, ±1 digit from 20 μF to 199.9 mF. |

| | |
|---|---|
| | HOLD: All specifications between 180 and 1999 counts same as AUTO. For all readings between 0 and 179 counts add: 0.1% of full scale to 19.99 μF (including 199.9 pF range), 0.5% of full scale from 19.99 μF to 199.9 mF. |
| **Reading Update Time** | 0.4 - 1.0 second to 20mF, increasing to 6 seconds at 200 mF. |
| **Zero Control** | Can compensate up to 25 pF of test lead capacitance, minus (−) sign indicates overcompensation in lowest range. |
| **Overrange Indication** | Blank display except for decimal point. On 200 mF range, (+) sign also displayed. |
| **GENERAL** | |
| **Display** | 3-½ digit, 0.5" LCD with low battery indicator. |
| **Front Panel Controls** | POWER ON-OFF switch, RANGE AUTO-HOLD switch, and zero adjust. |
| **Power Source** | 4 standard "C" cells operating from 4.2 to 6 volts, Nicad, alkaline, or zinc-carbon, with provision for ac adapter/charger. |
| **Battery Life** | 20 hours typical with alkaline batteries. |
| **Operating Temperature** | +15° to +35° C; usable at reduced accuracy 0° to +50° C. |
| **Dimensions** | 16 x 11 x 6 cm (6.4 x 4.4 x 2.4"). |
| **Weight** | 725 g (1.6 lb.) |

# OPERATING INSTRUCTIONS (refer to Fig. 1)

**WARNING**

1. **Never apply voltage to the test jacks; serious internal damage may result.**
2. **Fully discharge any capacitors before measurement.**
3. **Observe polarity when connecting polarized capacitors.**

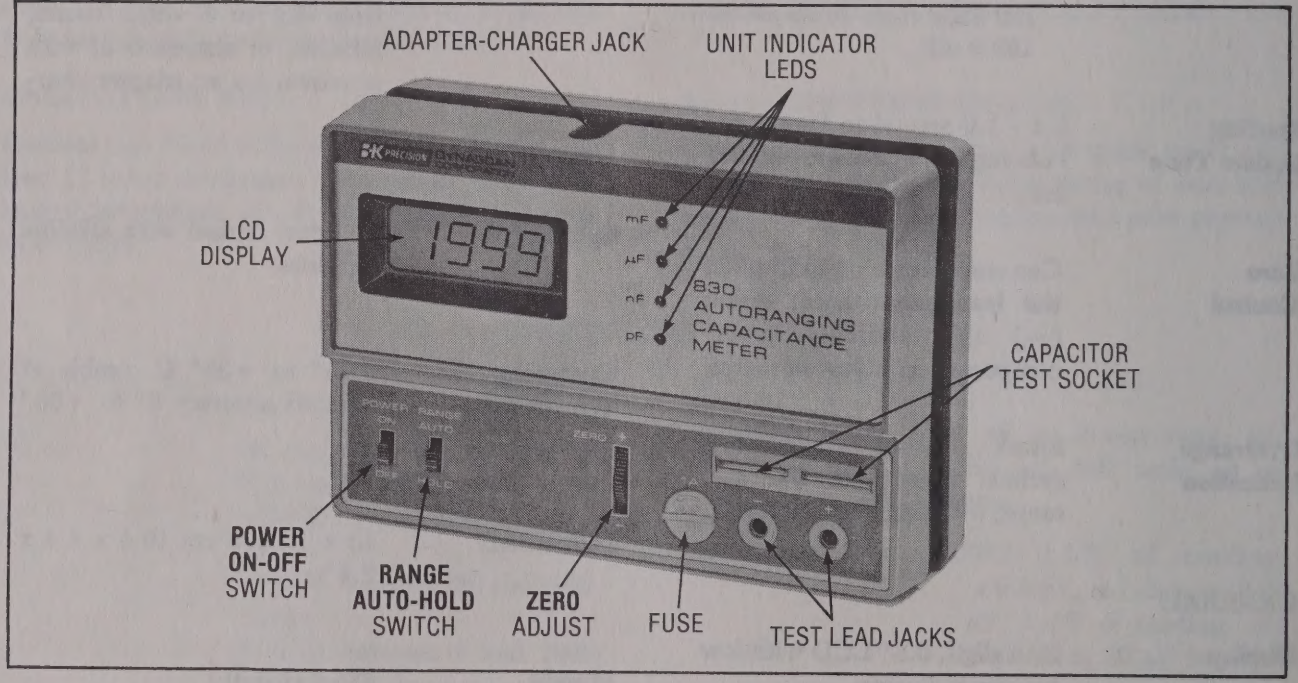



Fig. 1. Operating Controls.

## PREPARATION

The 830 is shipped without batteries so that fresh batteries can be installed when you are ready to start using the instrument. Select and install four "C" cells as described in the SERVICING section of this manual.

## PROCEDURE

1. Set the POWER switch to the ON position and the RANGE switch to the AUTO position.

2. Zero the meter. The display should read 00.0 and the minus ( − ) sign should not be displayed.

   a. A minus ( − ) sign indicates zero over-compensation. If the ( − ) sign is displayed, turn the ZERO adjust control in the + direction until the ( − ) sign *just* goes off and the display reads 00.0.

   b. If a number other than 00.0 is displayed, turn the ZERO adjust control in the - direction until the display *just* changes from 00.1 to 00.0.

   c. If test leads are to be used, connect them to the " + " and " − " jacks before zeroing the meter. *Do not short the leads together*; this will cause an overrange condition.

3. a. For all capacitors with leads, insert the capacitor leads directly into the slotted capacitor test socket.

   b. For capacitors which do not have leads, plug test leads into the " + " and " − " jacks and clip the test leads to the capacitor terminals.

4. Read the capacitance value directly from the LCD display and its accompanying unit indicator LED. For example, when the $\mu$F unit indicator is lighted and the LCD display reads 47.3, the value is 47.3 microfarads.

   a. A conversion chart is provided on the back of the meter for convenience and accuracy in converting nanofarads and millifarads into picofarad and microfarad values.

   b. The meter always starts on the lowest range (200 pF full scale) and automatically ranges upward to the range that will give maximum resolution (display of 180 to 1999 counts). The display remains blank until the proper range is reached. For values below 200 $\mu$F, the reading will appear in less than 1 second. The time required for the first reading increases with capacitance value to about 6 seconds for a 200 mF capacitor.

## OPERATING INSTRUCTIONS (Cont.)

c. Measurment of a group of similar value capacitors (especially large values over 200 μF) is faster if the RANGE switch is set to the HOLD position before the first capacitor is removed. The meter then locks on that particular range. Subsequent measurements do not require the automatic upranging sequence before a reading is obtained.

5. If the LO BAT indication appears in the display continuously, the batteries are nearing discharge. The instrument may be operated for 1 to 2 hours after the LO BAT indication first appears before accuracy is affected. It is normal for the LO BAT indication to appear momentarily when the unit is being turned off. Replace or recharge low batteries as applicable. See the SERVICING section of this manual for battery replacement procedures.

### CONSIDERATIONS

1. Recheck meter zero each time measurements are started in the AUTO mode, making sure that the last digit just changes from 1 to 0.

2. The LCD display blanks when the unit is autoranging to prevent erroneous readings from being displayed.

3. A shorted capacitor will cause the meter to overrange. It will range upward through all ranges, then display a plus ( + ) sign on the LCD display. The rest of the LCD display is blanked and the mF indicator LED is lighted.

4. An open capacitor will read a few picofarads in the AUTO mode, or zero if the meter is in the HOLD mode and locked on a higher range.

5. The spring-tensioned slot type capacitor test socket speeds testing. It accepts a wide variety of capacitor lengths, lead dimensions, and lead dress. This eliminates the time spent searching for a socket with correct spacing or accurately bending lead dress to match a socket.

6. If test leads are to be used, select test leads that are terminated in banana plus on one end and alligator clips on the other. Use short test leads to minimize cable capacitance. The meter will zero out at least 25 pF of test lead capacitance. Color coded test leads, one red and one black, simplify proper polarity connections.

7. Test leads with more than 25 pF cable capacitance may also be used, although the meter reading cannot be zeroed. Use the ZERO adjust to set the reading to a convenient value such as 20 pF, 50 pF or 100 pF, then subtract that value from each measurement. Of course, when measuring larger value capacitors, the test lead capacitance is such an insignificant proportion of the reading that it may be ignored.

8. When measuring an assortment of capacitors, where some will require test leads and some will not, leave the test leads connected to the meter throughout the measurements. Otherwise, it is necessary to zero out the test lead capacitance when test leads are connected, and rezero when they are removed.

9. The meter is protected against damage from charged capacitors by the fuse. If the fuse blows, the meter will read zero for all capacitors checked (a few pF on the 200 pF range). To remove the fuse, push and turn the cap counterclockwise. Replace the fuse only with a 1 Amp, type 3AG fuse.

10. To conserve battery life, turn the POWER switch off when not actually making measurements.

11. The optional accessory BC-28 Adapter/Charger is for use with *Nicad rechargeable batteries only*. Do not use the adapter/charger without batteries or when non-rechargeable batteries are installed in the meter.

12. The meter may be operated while the Nicad batteries are being charged. Operation of the meter is unaffected except on the 200 pF range. On that range only, resolution is reduced by ripple from the adapter/charger causing the least significant digit to vary over a range of 2 to 3 counts.

13. Remove discharged disposable batteries immediately to prevent leakage.

14. The 830 applies a maximum of 2.6 volts to the capacitor being measured. On some ranges, only 0.58 volt is applied. There is no danger of exceeding the voltage rating of any capacitor, nor of retaining a dangerous voltage on the capacitor when it is removed from the meter.

15. Capacitors, especially electrolytic, often have notoriously wide tolerances. Do not be surprised if the measured value is up to 100% greater than the value marked on the capacitor, unless it is a close tolerance type. However, values are seldom drastically below the rated value.

## OPERATING INSTRUCTIONS (Cont.)

16. A handy reference table, located on the inside rear cover of this manual, summarizes typical characteristics for various types of capacitors.

17. To measure cable capacitance, it is best to measure a short precise length, such as 3 feet, and calculate the total capacitance of a longer cable.

18. Capacitor leakage causes the measured value to be high. The relative effects of capacitor leakage on each range are summarized in the following table.

| RANGE | RANGE | RANGE |
|---|---|---|
| 1 200.0 pF | 4 200.0 nF | 8 2000 μF |
| 2 2000 pF | 5 2.000 μF | 9 20.00 mF |
| 3 20.00 nF | 6 20.00 μF | 10 200.0 mF |
| | 7 200.0 μF | |
| **LEAKAGE EFFECT** | **LEAKAGE EFFECT** | **LEAKAGE EFFECT** |
| 1 nA = .1% | 1 μA = .1% | 10 μA = .1% |
| 10 nA = 1% | 10 μA = 1% | 100 μA = 1% |
| 100 nA = 10% | 100 μA = 10% | 1 mA = 10% |
| % = percentage of full scale. | | |

Added effects of leakage on readings

# CIRCUIT DESCRIPTION

## INTRODUCTION

The block diagram (Fig. 3, located on centerfold) gives a functional breakdown of the meter. For detailed circuit operation, refer to the separately supplied schematic diagram. Fig. 2 is a timing diagram of the main events which occur in the meter's circuits during steady-state capacitance measurement. Most of the circuit descriptions are for the steady-state condition, which means that the autoranging sequence has been completed and the meter is on the correct range. Most of the exceptions to the steady-state condition are described in the "Autoranging" paragraphs, and Fig. 4 is a timing diagram of the main events during autoranging.

The capacitance meter uses the RC time constant property to measure capacitance. A specific charge voltage reference and precision charging resistors are provided by the meter. Charging time then becomes solely dependent upon the value of the capacitor being measured. A clock frequency ($f_O$) is counted during a specific portion of the capacitor charge period and the count is displayed on the liquid crystal display. The charging resistance, reference voltages, and $f_O$ frequency are selected to correlate the charge time to capacitance. Ten different combinations of $f_O$, resistance, and reference voltage provide ten ranges with full scale values of 199.9 pF to 199.9 mF. The values of resistance, reference voltage, and $f_O$ used for each range are summarized in Table 1.

Autoranging circuits automatically select the range with the greatest resolution; that is, the display reads between 200 and 1999. Automatic range selection includes selection of all the range variables listed in Table 1, plus placement of the decimal point in the LCD display and illumination of the appropriate pF, nF, $\mu$F, or mF units LED indicator.

## CLOCK FREQUENCY GENERATION

The basic clock frequency of the unit is 4 MHz, developed by crystal controlled oscillator/buffer IC14E & F. Crystal X1 gives a frequency stability of .005% (50 ppm), and no tuning adjustment is required for calibration. The 4 MHz signal is applied to the $f_O$ dividers consisting of IC10A & B and IC11A & B. The $f_O$ divider includes four decade dividers which provide frequencies of 400 kHz, 40

## CIRCUIT DESCRPITION (Cont.)

kHz, 4 kHz, and 400 Hz. One of these outputs or the 4 MHz signal is selected as the $f_O$ signal, depending upon the range. All $f_O$ signals other than the 4 MHz square wave are 20% high, 80% low duty cycle. An additional output signal at 800 Hz is applied to backplane dividers IC6B and IC8B, which produce a 40 Hz square wave. The 40 Hz square wave is used in the display backplane and is the input signal to the master clock circuit.

### MASTER CLOCK GENERATION

This circuit generates the MC (master clock) and $\overline{MC}$ (inverted master clock) signals shown in steady-state timing diagram, Fig. 2. MC divider IC25 converts the 40 Hz square wave from the backplane divider into three outputs of ÷ 2, ÷ 16, and ÷ 32. One of these outputs is selected as the basic MC signal in the MC gating/inverting circuit. The ÷ 2 output is selected by IC13C when the meter is autoranging to the correct range. This condition is commanded by speed-up flip-flop IC19B whenever it detects an overrange count. This shortens the period of the MC signal to more rapidly advance to the correct range.

The ÷ 32 output is selected by IC13A only on the 200 mF range (range 10). This condition is commanded by AND gate IC15D when the range 10 signal ($C_E$) is present. The ÷ 32 output lengthens the period of the MC signal because a longer capacitor discharge period is needed on range 10, and the capacitor discharge cycle is timed by the MC signal.

The ÷ 16 output is selected by IC13B. This is the normal condition in the steady-state condition after autoranging to the correct range, other than range 10. AND gate IC15C enables IC13B except when the speed-up flip-flop operates, or range 10 is selected.

The MC divider is inhibited during the capacitor charge cycle, and begins dividing the 40 Hz square wave at the end of the capacitor charge cycle. Therefore, the MC signal is a non-symmetrical pulse. The negative portion equals the capacitor charge period plus the selected divider period of IC25. The positive portion equals the selected divider period of IC25 only. Of course, for very small capacitors, the capacitor charge time is such a small proportion of the total cycle that the MC signal approaches a square wave. For larger capcitors, the waveform becomes progressively less symmetrical.

The $\overline{MC}$ signal is used to trigger the counter reset/zero adjust in the charge voltage reference cir-

cuits, and to establish the capacitor discharge period in the capacitor charge/discharge circuits. The positive-going transition of the MC signal is used in the display & driver circuits to initiate display update, and in the autoranging control circuits to clock the underrange decoder.

## CAPACITOR CHARGE CYCLE

The capacitor charge cycle begins as the $\overline{MC}$ signal makes its positive-going transition at the conclusion of its cycle. This transition triggers charge/discharge flip-flop IC18A, causing it to change state. The resulting logic low output of the flip-flop is applied to transistor switch Q108-Q109, turning it off and removing the short from across the capacitor being measured ($C_X$). This allows $C_X$ to start charging through a precision resistor path toward regulated +4.0 volts.

Two precision reference voltages are applied to dual comparator/inverter circuit IC106 and IC107, a lower and higher reference. As capacitor $C_X$

| RANGE | | COUNTING FREQ. ($f_O$) | CHARGE VOLTAGE (CVH) | CHARGING RESISTANCE | RC (SEC)* |
|---|---|---|---|---|---|
| 1 | 200.0 pF | 4 MHZ | 2.60 | 2.5 MΩ | $5 \times 10^{-4}$ |
| 2 | 2000 pF | 400 kHZ | 2.60 | 2.5 MΩ | $5 \times 10^{-3}$ |
| 3 | 20.00 nF | 40 kHZ | 2.60 | 2.5 MΩ | $5 \times 10^{-2}$ |
| 4 | 200.0 nF | 4 MHZ | 2.60 | 2.5 kΩ | $5 \times 10^{-4}$ |
| 5 | 2.000 μF | 400 kHZ | 2.60 | 2.5 kΩ | $5 \times 10^{-3}$ |
| 6 | 20.00 μF | 40 kHZ | 2.60 | 2.5 kΩ | $5 \times 10^{-2}$ |
| 7 | 200.0 μF | 4 kHZ | 2.60 | 2.5 kΩ | $5 \times 10^{-1}$ |
| 8 | 2000 μF | 4 kHZ | 2.60 | 250 Ω | $5 \times 10^{-1}$ |
| 9 | 20.00 mF | 4 kHZ | 0.58 | 250 Ω | $5 \times 10^{-1}$ |
| 10 | 200.0 mF | 400 Hz | 0.58 | 250 Ω | 5 sec |

* = for full scale reading

**Table 1.** Summary of range selection variables.

## CIRCUIT DESCRIPTION (Cont.)

charges, comparator IC107 changes state when the charge on $C_X$ reaches the lower reference voltage, producing signal CVL. Comparator IC106 produces a pulse when the charge on $C_X$ reaches the higher reference voltage, producing signal CVH. The CVH pulse resets charge/discharge flip-flop IC18A and ends the capacitor charge cycle.

The meter uses the time period required for the capacitor to charge from the lower reference voltage (CVL) to the higher reference voltage (CVH) to measure capacitance. The 3-½ digit counter circuit counts cycles of $f_O$ during this interval. The counter circuits are actually enabled for the entire capacitor charge cycle by the TS (transistor switch) signal, but are reset at CVL (may be delayed by zero adjust). Thus, the count at the end of the capacitor charge cycle is the count from CVL to CVH.

### CAPACITOR DISCHARGE CYCLE

The capacitor discharge cycle begins when the charge cycle ends. At that point, the CVH pulse resets charge/discharge flip-flop IC18A and the TS signal goes high. This turns on transistor switch Q108-Q109 and places an effective short-circuit across capacitor $C_X$, which provides the capacitor

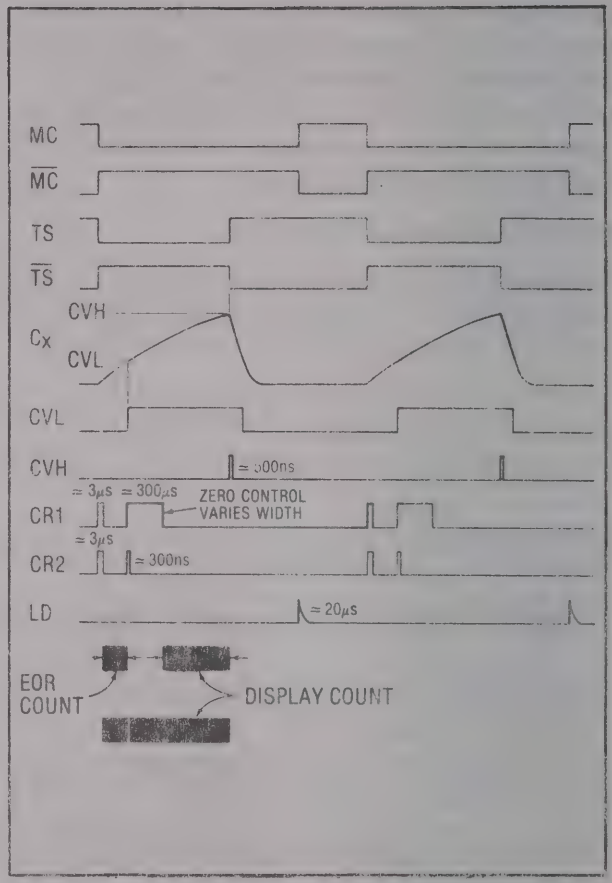



Fig. 2. Steady-state condition timing diagram.

discharge path. IC18A also provides the TS (inverted transistor switch) signal which resets the MC divider and enables it to resume divider action. The capacitor discharge condition continues for one full cycle of the MC divider, at which time the capacitor charge cycle again begins. The 3-½ digit counters are inhibited during the capacitor discharge cycle by the TS signal.

## CHARGE VOLTAGE REFERENCE

The 4.0 volt reference voltage is applied across voltage divider R135-R136 on all ranges. This establishes 0.20 volt as a lower reference voltage on comparator IC107. The capacitor charge voltage of $C_X$ is applied to the other input of the comparator. When the charge voltage is below the reference, the output of IC107 is high. When the charge voltage exceeds the reference, the output changes states. The inverted output of IC107, by inverter IC105D, is the CVL signal.

On ranges 1 thru 8, the 4.0 reference voltage is applied across voltage divider R131-R132, which establishes 2.60 volts as the higher reference voltage on comparator IC106. On ranges 9 and 10, transistor Q107 is turned on. This connects R134 in parallel with R132 and drops the higher reference voltage on IC106 to 0.58 volt. In either case, IC106 detects the point at which the charge voltage exceeds the reference voltage. The inverted output of IC106, by inverter IC105C, is the CVH signal. Since the CVH transition initiates the capacitor discharge cycle, the $C_X$ charge voltage immediately drops below the higher reference voltage. Thus, CVH is a narrow pulse.

For a capacitor charging from 0 to 4.0 volts, which requires at least 5 RC time constants, the charge from 0.20 volt to 2.60 volt requires 1 RC time constant. The charge from 0.20 to 0.58 volt requires 0.1 RC time constant. This provides a decade step for measuring higher value capacitors.

## CHARGING RESISTORS

On ranges 1 thru 3, capacitor $C_X$ charges through resistors R123 and R124, a nominal resistance of 2.5 Megohms. On ranges 4 thru 7, transistor Q105 is turned on. This connects R126 and R127 in parallel with R123-R124 and drops the total resistance to 2.5 kilohms. On ranges 8 thru 10, transistor Q106 is turned on and Q105 is again turned off. This places R129 and R130 in parallel with R123-R124 and drops the total charging resistance to 250 ohms. The four 10:1 steps of $f_O$ frequency, the 1000:1 and 10:1 steps of charging resistance, and the change of

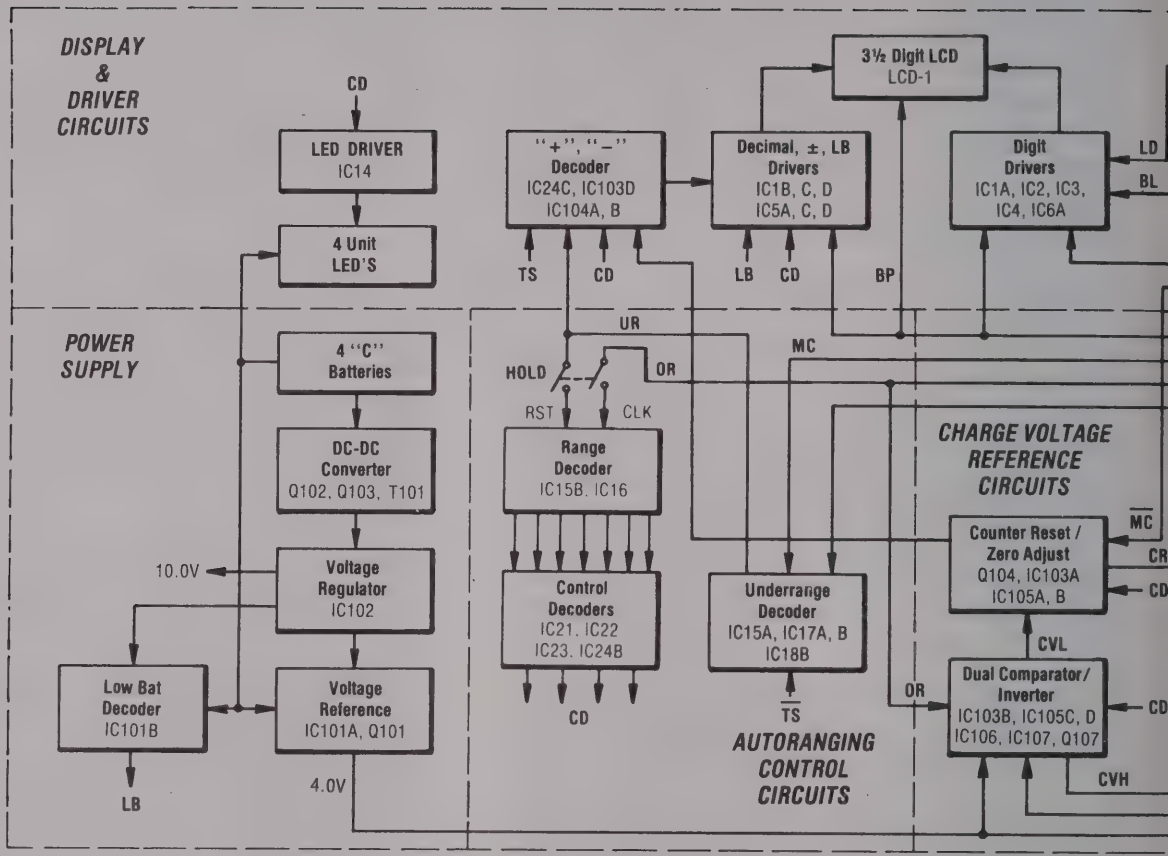
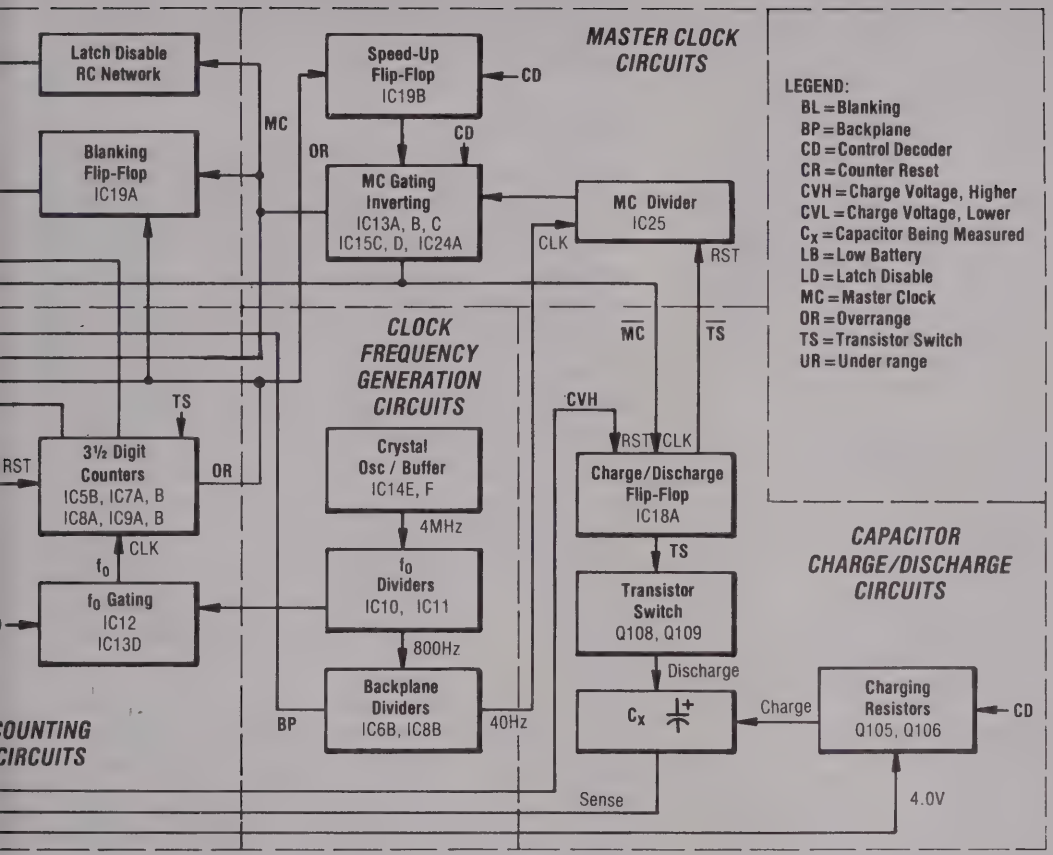





Fig. 3. Block Diagram.


MASTER CLOCK CIRCUITS
Latch Disable RC Network
Speed-Up Flip-Flop IC19B
CD
MC
OR
CD
Blanking Flip-Flop IC19A
MC Gating Inverting IC13A, B, C IC15C, D, IC24A
MC Divider IC25
CLK
RST
LEGEND:
BL = Blanking
BP = Backplane
CD = Control Decoder
CR = Counter Reset
CVH = Charge Voltage, Higher
CVL = Charge Voltage, Lower
$C_X$ = Capacitor Being Measured
LB = Low Battery
LD = Latch Disable
MC = Master Clock
OR = Overrange
TS = Transistor Switch
UR = Under range
CLOCK FREQUENCY GENERATION CIRCUITS
$\overline{MC}$
$\overline{TS}$
TS
CVH
RST
3½ Digit Counters IC5B, IC7A, B IC8A, IC9A, B
OR
RST CLK
Crystal Osc / Buffer IC14E, F
Charge/Discharge Flip-Flop IC18A
4MHz
CLK
$f_0$
$f_0$ Gating IC12 IC13D
$f_0$ Dividers IC10, IC11
TS
Transistor Switch Q108, Q109
800Hz
Discharge
CAPACITOR CHARGE/DISCHARGE CIRCUITS
Backplane Dividers IC6B, IC8B
BP
40Hz
$C_X$
Charge
Charging Resistors Q105, Q106
CD
COUNTING CIRCUITS
Sense
4.0V

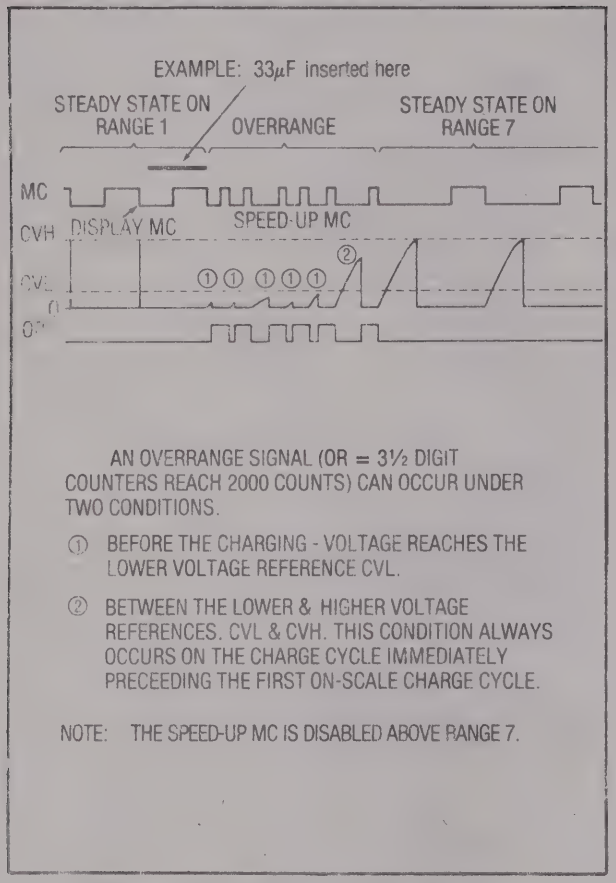

EXAMPLE: 33μF inserted here
STEADY STATE ON RANGE 1
OVERRANGE
STEADY STATE ON RANGE 7
MC
CVH
DISPLAY MC
SPEED-UP MC
CVL
OR
AN OVERRANGE SIGNAL (OR = 3½ DIGIT COUNTERS REACH 2000 COUNTS) CAN OCCUR UNDER TWO CONDITIONS.
① BEFORE THE CHARGING - VOLTAGE REACHES THE LOWER VOLTAGE REFERENCE CVL.
② BETWEEN THE LOWER & HIGHER VOLTAGE REFERENCES. CVL & CVH. THIS CONDITION ALWAYS OCCURS ON THE CHARGE CYCLE IMMEDIATELY PRECEEDING THE FIRST ON-SCALE CHARGE CYCLE.
NOTE: THE SPEED-UP MC IS DISABLED ABOVE RANGE 7.

Fig. 4. Autoranging timing diagram.

reference voltage that provides a 10:1 step in RC time are combined to provide 10 decade ranges of capacitance measurement.

## AUTORANGING

When a capacitor is connected for measurement, the capacitance meter always starts on the lowest range (range 1) and takes a reading. If the reading is overrange (count greater than 2000), the meter automatically steps to the next higner range. The process is repeated until an on-scale reading is obtained. This gives the greatest resolution for all measurements. If a reading of less than 180 counts is obtained, the meter underranges and resets to range 1. This normally occurs only when the capacitor is removed from the meter, but could occur from a large change in capacitance. The HOLD position of the RANGE AUTO/HOLD switch prevents the meter from resetting to range 1 when the capacitor is removed. The HOLD position also prevents upranging.

The autoranging sequence occurs as follows (see Fig. 3 and 4). With no capacitor connected, the meter is on range 1 and the MC divider is operating at the ÷ 16 rate. With no capacitor connected, the voltage at the $C_X$ terminals quickly reaches the lower and higher charge voltage references during

the capacitor charge cycle. If the zero adjust is properly set, a zero reading should be obtained. This sequence repeats at the ÷ 16 MC rate.

When a capacitor is connected, a finite time is required for the capacitor to reach the lower and higher charge voltage references. If the capacitor is very large, the 3-½ digit counters will reach a full count of 2000 before the capacitor even reaches the lower charge voltage reference. This is called the EOR (extreme overrange) condition. A full count produces the OR (overrange) output from the 3-½ digit counters. The OR signal performs several functions as follows:

- It clocks the range decoder, IC16, to the next higher range. In turn, the control decoders select the range variables to allow measurement of a decade larger capacitor.
- It ends the capacitor charge cycle by resetting charge/discharge flip-flop IC18A through OR gate IC103B.
- It triggers speed-up flip-flop IC19B, which changes the MC divider to the ÷ 2 rate. This speeds up the autoranging process to quickly advance to the correct range. Since the MC rate is also the capacitor discharge period, the speed-up flip-flop is inhibited on ranges 8, 9, and 10 to allow sufficient discharge time for large value capacitors.
- It triggers blanking flip-flop IC19A to blank the display until the correct range is reached.

This process is repeated until a range is reached where the 3-½ digit counters do not overrange before the lower charge voltage reference is reached during the capacitor charge cycle. The CVL signal is then produced, which results in the CR (counter reset) pulse. The 3-½ digit counters reset at CVL, then continue counting as the capacitor charges toward the higher charge voltage reference. On this range, the counters will overrange before the capacitor reaches the higher reference and advance one more range. This is the correct range, on which the 3-½ digit counter will not overrange. Without the OR pulse, the MC divider switches back to the ÷ 16 rate and a reading is taken as described for the steady state condition.

Gate IC15B prevents the OR pulse from clocking range decoder IC16 after it reaches range 10. It is unlikely that a capacitor larger than 200 mF will be measured to cause an overrange condition on range 10, but a shorted capacitor or a resistive path across the $C_X$ terminals could cause such a condition. Such

## CIRCUIT DESCRIPTION (Cont.)

conditions prevent the $C_X$ voltage from ever reaching the higher charge voltage reference. In such cases, the meter remains on range 10 and the + sign is displayed to indicate the condition. The range 10 signal, $C_E$, enables "+" decoder IC104B. If the OR signal is generated while the "+" decoder is enabled, it turns on the "+" sign in the LCD display.

When the capacitor being measured is removed from the meter, or for any other reason a count of less than 180 occurs, the meter automatically resets to range 1. This action is accomplished by the underrange decoder circuit. Type D flip-flop IC18B is set by the TS signal, effectively enabling it during the capacitor discharge cycle. The flip-flop is clocked by the positive-going transition of the MC signal at the center of the capacitor discharge period. Gates IC15A and IC17A & B detect whether the 3-½ digit counters reached a count of 180 or greater during the previous capacitor charge cycle and apply the result to the "D" input of the flip-flop. If the count is less than 180 when IC18B is clocked, the UR (underrange) signal results. The UR signal resets range decoder IC16 to range 1.The HOLD position of the RANGE AUTO-HOLD switch opens the UR signal path and holds the range decoder in the previous range when a capacitor is removed. The autoranging circuits can still up-range if a larger capacitor is subsequently connected.

### RANGE DETERMINATION

Range decoder IC16 is a counter that advances one count with each overrange pulse and is reset by the underrange pulse during the autorranging sequence. The outputs of the range decoder are gated to perform various functions on each range by control decoders IC21, IC22, IC23, and IC24B. The logic states of the control decoder outputs, identified as signals $C_A$ thru $C_L$ on the schematic diagram, are listed in Table 2 for each range. The functions of these signals are as follows:

$C_A$ selects 4 MHz $f_O$ frequency on ranges 1, 4.

$C_B$ selects 400 kHz $f_O$ frequency on ranges 2, 5.

$C_C$ selects 40 kHz $f_O$ frequency on ranges 3, 6.

$C_D$ selects 4 kHz $f_O$ frequency on ranges 7-9.

$C_E$ and $\overline{C_E}$ selects 400 Hz $f_O$ frequency, selects ÷ 32 MC rate, enables "+" decoder, and inhibits up-ranging of range decoder on range 10.

$C_F$ selects 2.5 kilohms charging resistance on ranges 4-7.

$C_G$ selects 250 ohms charging resistance and inhibits speed-up flip-flop on ranges 8-10.

$C_H$ selects mF LED and selects 0.58V CVH on ranges 9-10.

$C_I$ selects μF LED on ranges 5-8.
$C_J$ selects nF LED on ranges 3-4.
$C_K$ selects pF LED on ranges 1-2.
$C_L$ enables front panel zero adjust on ranges 1-3.
Additional outputs control the placement of the decimal point on the 3½ digit LCD display.

## DISPLAY & DRIVER CIRCUITS

The display & driver circuits encompass those devices that are directly involved in producing the digital readout on the 3-½ digit LCD display and the unit LED's. This includes all circuits identified as the "Display & Driver Circuits" area of Fig. 3.

The 3-½ digit counters are enabled by the TS signal throughout the capacitor charge cycle, and reset when the CR (counter reset) signal is high. The counters are inhibited from counting until the CR signal goes back low. The counters start counting clock frequency $f_O$ until the lower charge voltage reference CVL is reached. The counter than resets again (and start of counting is delayed by a zero adjust interval on ranges 1, 2, and 3) and counts until

| RANGE | | $C_A$ | $C_B$ | $C_C$ | $C_D$ | $C_E$ | $C_F$ | $C_G$ | $C_H$ | $C_I$ | $C_J$ | $C_K$ | $C_L$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 200.0 pF | H | L | L | L | L | L | L | L | L | L | H | L |
| 2 | 2000 pF | L | H | L | L | L | L | L | L | L | L | H | L |
| 3 | 20.00 nF | L | L | H | L | L | L | L | L | L | H | L | L |
| 4 | 200.0 nF | H | L | L | L | L | H | L | L | L | H | L | H |
| 5 | 2.000 μF | L | H | L | L | L | H | L | L | H | L | L | H |
| 6 | 20.00 μF | L | L | H | L | L | H | L | L | H | L | L | H |
| 7 | 200.0 μF | L | L | L | H | L | H | L | L | H | L | L | H |
| 8 | 2000 μF | L | L | L | H | L | L | H | L | H | L | L | H |
| 9 | 20.00 mF | L | L | L | H | L | L | H | H | L | L | L | H |
| 10 | 200.0 mF | L | L | L | L | H | L | H | H | L | L | L | H |

**Table 2.** 830 control signals

the higher charge voltage reference CVH is reached. At this point, signal TS disables the counters. The count stored in the counter will thus be the count achieved while the capacitor charged from CVL to CVH. This count remains in the counter until the LD (latch disable) pulse occurs at the middle of the capacitor discharge cycle. The LD signal is a differentiated pulse derived from the positive-going transition of the MC signal. The LD pulse transfers the count into the digit drivers, which latch the data and convert it to segment lighting of the LCD digits. The backplane square wave refreshes the display at a 40 Hz rate. The blanking flip-flop inhibits the display during autoranging (OR signal is present).

The counter is reset at the beginning of each capacitor charge cycle and takes another count of the capacitor being measured. The readout is updated in the middle of each capacitor discharged cycle when the new count is transferred into the digit drivers by the LD signal.

The decimal point and the "+", "−", and "LB" display portions of the LCD display are lighted by a direct connection from a driver to each element. The control decoder determines which decimal point should be lighted and activates the corresponding driver. The "+", "−", and "LB" elements are each controlled by a decoder which is described elsewhere.

The four unit LED's, which are separate from the LCD display, are individually driven by signals from the control decoder. The control decoder senses the operating range and lights the corresponding unit LED to notify the operator whether the indicated value is in pF, nF, $\mu$F, or mF.

**ZERO ADJUST**

The zero adjust circuit permits compensation for test lead capacitance up to 25 pF (250 counts on range 1). The start of counting is delayed until the capacitor charge cycle has started, effectively burying enough $f_O$ counts to compensate for test lead capacitance. The ZERO adjust varies the delay.

The CR (counter reset) signal is derived in the counter reset/zero adjust circuit. The positive-going transition of the MC signal is coupled through an RC network into IC103A. The time constant of the RC network results in an approximate 3 $\mu$s pulse in the output of IC103A.

The CVL signal is applied through IC105B and an RC network to IC105A. On ranges 4 thru 10, transistor Q104 is turned on, and C110 and R119 from the RC network. The short time constant of this

network results in an approximate 300 ns pulse in the output of IC105A. On ranges 1 thru 3, Q104 is turned off. The RC network is now formed by C110, R121, and ZERO adjust control R4. This produces a nominal 300 $\mu$s pulse which can be varied considerably in width by the ZERO control.

The 3 $\mu$s pulse is serially combined with either the 300 ns pulse or the variable width pulse in IC103A, resulting in the CR signal. The 3-½ digit counters are reset by the high level CR signal and are inhibited from counting until the CR signal goes low. The ZERO control varies the delay from the CVL signal to the end of the CR signal on ranges 1-3. During this delay period, the $f_O$ count is buried because the capacitor charge cycle continues but the counter is not counting.

If 200 counts of the 4 MHz $f_O$ are buried on range 1, for example, only 20 counts are buried on range 2 when the $f_O$ rate drops to 400 kHz, and 2 counts are buried on range 3 when the $f_O$ rate drops to 40 kHz. The zero adjust accuracy is thus maintained on all three most sensitive ranges. On higher ranges, test lead capacitance is an insignificant portion of the total capacitance and no counts should be buried. Thus, the variable width pulse is replaced by the narrow 300 ns pulse on ranges 4-10.

If the ZERO adjust is overcompensated, the display will still read zero, but extra counts may be buried and cause measurements to be low. The " – " decoder detects overcompensation. The variable width pulse from IC105A enables the " – " decoder, IC104A. If overcompensation occurs, the TS signal goes positive before the variable width pulse ends. The " – " decoder then lights the " – " sign of the LCD display.

## POWER SUPPLY

The capacitance meter operates from four "C" cells which provide 4.2 to 6 volts, depending upon the degree of battery charge. Raw battery voltage is used to power circuits where 4.2 to 6-volt power is used and regulation is not critical. Battery voltage is also applied to a DC-to-DC converter consisting of transistors Q102 and Q103, transformer T101 and diodes D101 and D102. The DC-to-DC converter operates at approximately 15 kHz and converts the battery voltage to a 13- to 20- volt DC output which is applied to regulator IC102. The regulator provides regulated 10.0 volts for most of the digital circuits, and a 4.0-volt reference voltage for IC101A. IC101A compares the actual source voltage for the charging resistance and charge voltage reference circuit with the 4.0-volt reference and controls

series pass regulator transistor Q101 to accurately regulate the 4.00 volt reference.

Low battery decoder IC101B compares the battery voltage with a regulated 4.3 volt reference which is derived by a voltage divider connected to the regulated 10.0 volt source. The LO BAT segment of the LCD display is lighted if the battery voltage drops below the reference. The LO BAT indication appears below 4.3 volts, but accurate measurements can be made until the voltage drops to 4.2 volts. This gives the operator a 1 to 2 hour notice before use must be interrupted for battery replacement or charging.

The LO BAT indication appears momentarily when the POWER switch is turned OFF because the battery voltage decays faster than the 10.0V reference, causing low battery decoder IC101B to operate.

## PROTECTIVE CIRCUITS

**CAUTION**

**Although the meter is equipped with protective circuits, capacitors should always be discharged before connecting them to the meter for measurement. A high voltage charge or transient could exceed the limitations of the protective circuits and damage the instrument.**

Diode D1 gives protection against reverse polarity input at the battery charger jack. Diodes D103 and D104 and fuse F1 give protection if a charged capacitor is accidentally connected to the meter. If the charged capacitor is connected in the proper polarity, but the potential is greater than the battery voltage, diode D103 allows the battery to act as a filter and absorb the charge. If the charged capacitor is connected with reverse polarity, diode D104 shorts the charge to ground. If the amount of charge is excessive, fuse F1 opens the capacitor's ground return path.

# SERVICING

## BATTERY REPLACEMENT

This instrument operates from four standard "C" size flashlight cells. Ni-cad or alkaline batteries are recommended. Select batteries from Table 3.

Batteries must be installed when the meter is initially placed in service. Subsequently, non-rechargeable batteries must be replaced within 1 to 2 hours operating time after the LO BAT indicator of the LCD display appears; ni-cad type batteries must be recharged. If alkaline or zinc-carbon types are used, low batteries should be removed immediately to prevent instrument damage from battery leakage.

1. Loosen the captive screw from the back of the unit and remove the back cover (see Fig. 5).
2. Install or replace the four "C" cells with the polarity shown in the battery compartment.

**FLASHLIGHT SIZE "C" BATTERIES**

| Type | NEDA | Burgess | Eveready | Mallory | RCA | Ray-O-Vac |
|---|---|---|---|---|---|---|
| Zinc-Carbon | 14F | 1 | 935 | M14F | VS035A | 1C |
| Alkaline | 14A | AL1 | E93 | Mn1400 | VS1335 | 814 |

**RECHARGEABLE BATTERIES**

| Type | Burgess | Eveready | General Electric | Gould | Gulton |
|---|---|---|---|---|---|
| Ni-Cad | CD-14 | CH-1.5 | GCT 1.5 SB | 2.0SC | R-190 |

**Table 3.** Battery selection guide

## SERVICING (Cont.)

**DISASSEMBLY (refer to fig. 5)**

NOTE

For best results, the unit should always be powered from batteries, including bench testing, troubleshooting, and calibration adjustments of the disassembled instrument. The ripple from most power supplies may adversely affect the meter's stability.

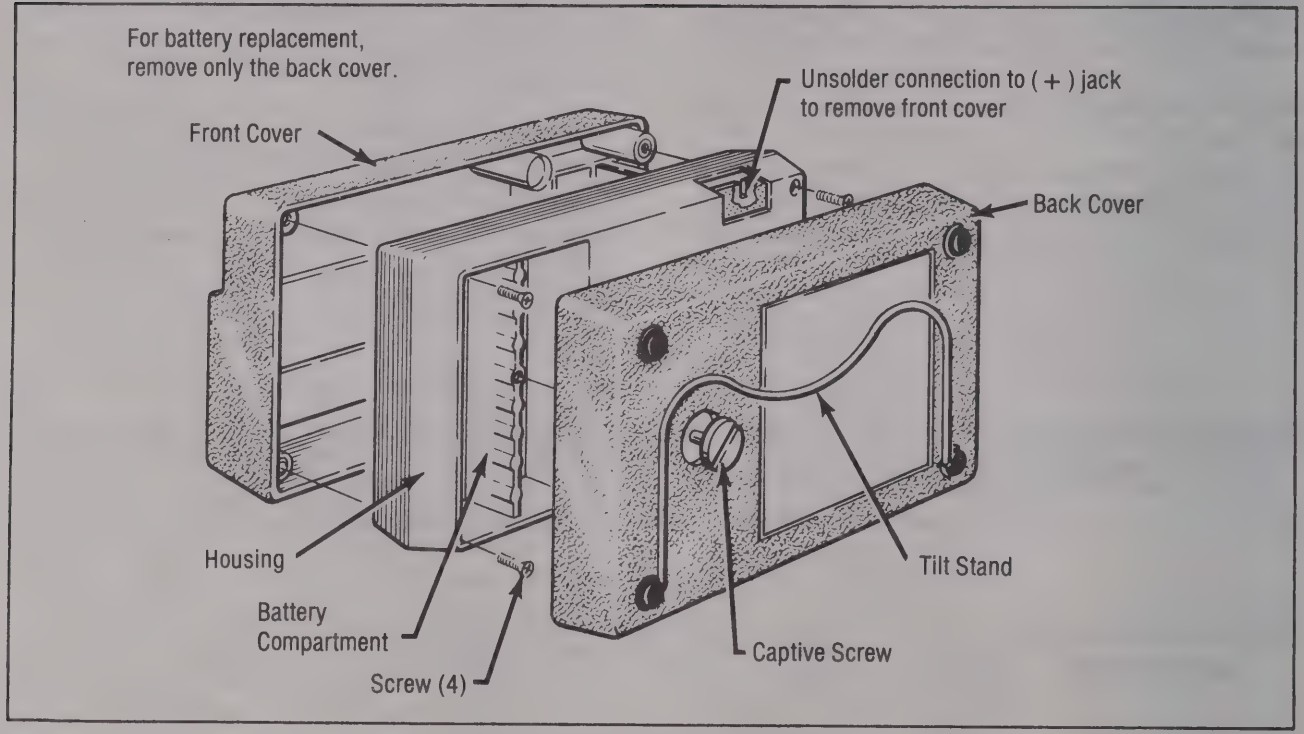



**Fig. 5.** Disassembly

1. Remove the back cover and batteries as for battery replacement.

2. Remove the fuse from the front panel.

3. Unsolder the connection from the display board to the (+) jack of the front panel.

4. Remove four screws, one from each corner of the inside of the housing, and remove the front cover.

5. The entire display (top) circuit board is now accessible, as is enough of the bottom board to perform calibration adjustment procedures. To power unit from batteries at this stage of disassembly, merely replace the batteries. Either place the housing on a flat surface or replace the back cover to hold the batteries in the compartment.

6. Both circuit boards may be completely removed from the housing for access to the bottom board and for parts replacement. Remove one screw from the approximate center of each board, then compress the battery terminals and push them through the slots in the housing. Leave both boards interconnected. To power the disassembled unit from batteries, leave the bottom board extended from the housing and replace the display board. Access to both boards is now possible while providing an electrical connection to the battery compartment.

## BASIC TROUBLESHOOTING HINTS

### Blown Fuse

If the front panel fuse is blown and the 830 is in the AUTO mode, the meter will read a few pF for all value capacitors (will not uprange). In the HOLD mode, it will read zero or at the extreme bottom of the range it's locked on.

### Batteries Inserted Backwards

If the polarity of one battery is reversed, the LO BAT indicator comes on. If two batteries are reversed, the effective supply voltage is zero and nothing works. If three, or all four batteries are inserted backwards, possible circuit damage may result. The components most likely to go are D103, D104, and Q108.

### All Display Segments Lighted

If all segments including the LO BAT, "±", and decimal points come on, turn the unit off immediately. Otherwise, the LCD display will be *permanently* damaged. The BP signal is probably abnormal

## SERVICING (Cont.)

### Checkout of Autoranging

A quick check of autoranging operation may be performed by inserting a short between the " + " and " – " jacks. The display will blank and the 830 will step through its 10 ranges, one at a time, until it locks up on the top range. The display remains blank and the " + " sign comes on and stays on until the short is removed. As the 830 steps through its ranges, the associated LED lights and the decimal points shift.

### Autoranging Caught in Loop

A missing or incorrect control decoder signal can cause the autoranging circuits to get caught in a loop (upranging and reset to range 1 repeatedly without reaching the correct range). The 830 may work normally on the lower ranges in some cases. Selecting the HOLD mode breaks the loop and places the 830 in a steady-state condition, which may permit more effective troubleshooting. Check control decoder signals $C_A$ thru $C_L$.

## CALIBRATION ADJUSTMENTS

The unit was carefully checked and calibrated at the factory prior to shipment. Readjustment is recommended only if repairs have been made in a circuit affecting calibration, or if you have reason to believe the unit may be out of calibration. Recalibration should be attempted only if you have the recommended test equipment and calibration standard capacitors. The accuracy of the instrument will be degraded if less accurate calibration standards are used. Very few instrument shops have standard capacitors of the precision required to calibrate this instrument. Your Model 830 Capacitance Meter will be adjusted to its original accuracy if returned to the B & K-Precision factory service department for recalibration.

### Test Equipment Required

DC Voltmeter, 0.25% accuracy or better (B & K-Precision Model 2815 or 2831 or equivalent).

Four miniature alligator clips and a 1-amp fast-blow pigtail fuse wired per Fig. 6.

Precision capacitors of 1000 pF (±0.05%), 1.000 μF (±0.05%), and 1000 μF (±0.2%). Values of capacitance may by approximate (as long as the value is accurately known), but the tolerance must not exceed that specified.

### Procedure

Perform adjustments only in the sequence listed. Locations of adjustments are shown in Fig. 6.

1. Make sure the LO BAT indicator is off. Replace batteries if necessary.
2. Remove the front and back covers as shown in Fig. 5, then replace the batteries. Do not use a power supply. Circuit boards should remain in the housing for calibration adjustments.
3. Measure the dc voltage at the 4.00 V test point (see Fig. 6) with respect to circuit common.
4. Adjust R111 for a reading of 4.00 volts on the dc voltmeter.
5. Connect the special, short test leads with 1-amp pigtail fuse as shown in Fig. 6 to the circuit board points equivalent to the (+) and (−) jacks, but without the precision capacitor.
6. ZERO the meter.
7. Connect the 1000 pF precision capacitor and adjust R124 so the meter reads the exact value of the precision capacitor.
8. Connect the 1.000 $\mu$F precision capacitor and adjust R127 so the meter reads the exact value of the precision capacitor.
9. Connect the 1000 $\mu$F precision capacitor and adjust R130 so the meter reads the exact value of the precision capacitor.

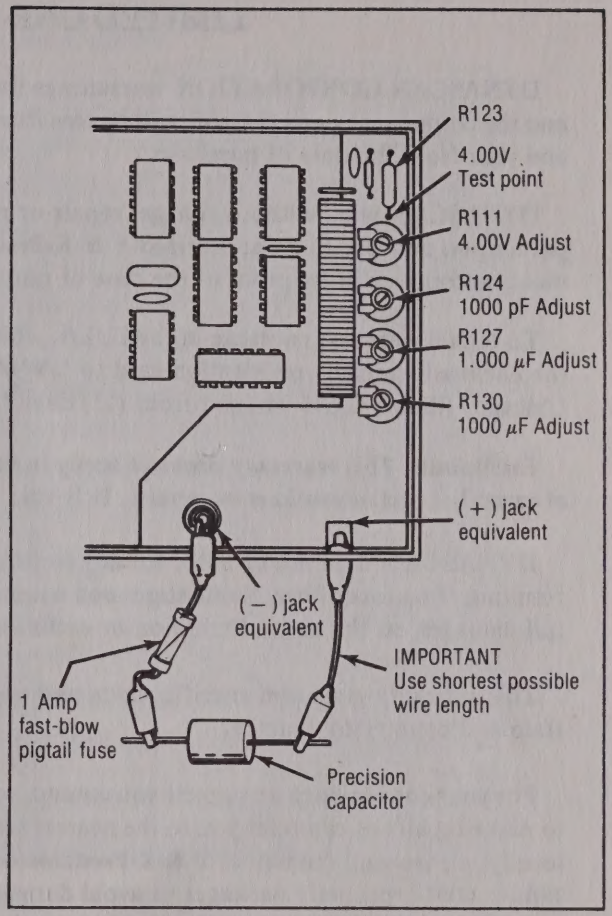



Fig. 6. Calibration adjustments

# LIMITED ONE-YEAR WARRANTY

DYNASCAN CORPORATION warrants to the original purchaser that its **B & K-Precision** product, and the component parts thereof, will be free from defects in workmanship and materials for a period of one year from the date of purchase.

DYNASCAN will, without charge, repair or replace, at its option, defective product or component parts upon delivery to an authorized **B & K-Precision** service contractor or the factory service department, accompanied by proof of the date of purchase in the form of a sales receipt.

To obtain warranty coverage in the U.S.A., this product must be registered by completing and mailing the enclosed warranty registration card to DYNASCAN, **B & K-Precision,** 6460 West Cortland Street, Chicago, Illinois 60635 within fifteen (15) days from the date of purchase.

**Exclusions: This warranty does not apply in the event of misuse or abuse of the product or as a result of unauthorized alterations or repairs. It is void if the serial number is altered, defaced or removed.**

DYNASCAN shall not be liable for any consequential damages, including without limitation damages resulting from loss of use. Some states and countries do not allow limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you.

This warranty gives you specific rights and you may also have other rights which vary from state to state and country to country.

For your convenience we suggest you contact your **B & K-Precision** distributor, who may be authorized to make repairs or can refer you to the nearest service contractor. If warranty service cannot be obtained locally, please send the unit to **B & K-Precision** Service Department, 2815 W. Irving Park Rd., Chicago, Illinois 60618, properly packages to avoid damage in shipment. Outside the U.S.A., contact the Service Department for the name of the closest service center.

## TYPICAL CAPACITOR CHARACTERISTICS

| TYPE | VALUE | VOLTAGE | TEMPCO | DF | DA | LEAKAGE |
|---|---|---|---|---|---|---|
| **Glass and Mica** | | | | | | |
| Glass | 0.5pF – .01 μF | 300 – 1kV | +140 ±25 | .03 – 0.1% | | $10^9$ |
| High K Glass | 10 pF – .01 μF | 50 – 100 | ±4500 | 1 – 3% | | $10^9$ |
| Mica | 1 pF – 0.1 μF | 100 – 2kV | ±500 to ±10 | .05 – 0.2% | 0.7% | $10^9 - 10^{11}$ |
| **Ceramic** | | | | | | |
| COG | 1 pF – 0.1 μF | 50 – 600 | 0±30 | 0.2% | | $10^8$ |
| COH | 1 pF – .01 μF | 50 – 600 | 0±60 | 0.2% | | $10^8$ |
| COJ | 1 pF – .01 μF | 50 – 600 | 0±120 | 0.2% | | $10^8$ |
| COK | 1 pF – .01 μF | 50 – 600 | 0±250 | 0.2% | | $10^8$ |
| P3K | 100 pF – .01 μF | 50 – 600 | –1500 ±250 | 0.2% | | $10^8$ |
| S2L | 3 – 200 pF | 1kV – 6kV | –330 ±500 | 0.6% | | $10^7$ |
| S3N | 3 – 200 pF | 1kV – 6kV | –3300 ±2500 | 0.6% | | $10^7$ |
| U2J | 1 pF – .01 μF | 50 – 600 | –1500 ±250 | 0.2% | | $10^8$ |
| X5F | 100 pF – .01 μF | 50 – 600 | –500 ±2500 | 2% | | $10^4 - 10^{10}$ |
| X5U | 100 pF – .01 μF | 50 – 6kV | ±2000 | 2% | | $10^4 - 10^{10}$ |
| X7R | 10 pF – 2.7 μF | 50 – 100 | +1000 ±3000 | 2.5% | | $10^8 - 10^9$ |
| Y5F | .01 – 2.2 μF | 3 – 50 | ±2500 | 2 – 10% | | $10^5 - 10^8$ |
| Y5R | .01 – 2.2 μF | 3 – 50 | ±3000 | 2 – 10% | | $10^5 - 10^8$ |
| Y5T | .01 – 2.2 μF | 3 – 50 | +1000 ±4000 | 2 – 10% | | $10^5 - 10^8$ |
| Y5V | 470 pF – 4.7 μF | 50 – 100 | ±20,000 | 2.5% | | $10^9$ |
| Z5F | 100 pF – .01 μF | 50 – 6kV | ±2000 | 2% | | $10^4 - 10^{10}$ |
| Z5P | .001 – .01 μF | 50 – 6kV | +2500 ±2500 | 2% | | $10^4 - 10^{10}$ |
| Z5R | .005 – 0.1 μF | 50 – 6kV | +2500 ±2500 | 2% | | $10^4 - 10^{10}$ |
| Z5U | .001 – 4.7 μF | 50 – 6kV | ±10,000 | 2% | | $10^4 - 10^{10}$ |
| Z5V | .001 – 0.1 μF | 50 – 600 | ±10,000 | 2% | | $10^4 - 10^{10}$ |
| **Paper and Plastic** | | | | | | |
| Mylar | .001 – 10 μF | 50 – 1600 | +400 ±200 | 0.5 – 1% | 0.5% | $10^9 - 10^{11}$ |
| Paper | .0005 – 100 μF | 200 – 15kV | 0±500 | 0.2 – 1% | 2% | $10^9 - 10^{10}$ |
| Parylene | .001 – 1 μF | 30 – 100 | 0±50, –200 | 0.1 – 0.3% | 0.1 – 1% | $10^{10} - 10^{12}$ |
| Polycarbonite | .001 – 25 μF | 50 – 400 | 0±100 | 0.1 – 0.5% | 0.2% | $10^{10} - 10^{11}$ |
| Polystyrene | 20 pF – 30 μF | 30 – 600 | –120 ±30 | .01 – 0.1% | .02% | $10^{11} - 10^{12}$ |
| Teflon | .001 – 1 μF | 50 – 600 | –200 | 0.1 – 0.2% | 0.2% | $10^{11} - 10^{12}$ |
| **Electrolytic** | | | | | | |
| Aluminum Foil | 0.5 μF – 1F | 3 – 500 | +10,000 | 3 – 50% | 10% | .01 – 10μA |
| Tantalum Foil | 0.1 – 10,000 μF | 3 – 500 | +2500 | 10 – 20% | | .01 – 1μA |
| Solid Tantalum | .001 – 1000 μF | 3 – 125 | +1000 | 1 – 12% | 2% | .01 – 10μA |

TEMPCO = temperature coefficient in ppm per °C.
DF = dissipation factor @1kHz, except electrolytics @120Hz, Mica @1MHz.
DA = dielectric absorption.
LEAKAGE = ohms x μF, except electrolytics = μA per μFV.

B+K PRECISION DYNASCAN CORPORATION

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